ENTRAINMENT-MIXING IN SHALLOW CUMULUS AND THE ONSET OF PRECIPITATION

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Objectives

What are the controling factors of the onset of precipitation in shallow cumulus ??

Cloud droplets have to grow by condensation up to a size big enough for the collection process to become efficient (> 40 μm in diameter) :

Precipitation Embryos

Additional processes have been considered, beyond homogeneous condensation, to explain enhanced growth of such big droplets : GCCN, droplet clustering, turbulence enhanced collision, radiative cooling, …..

Is the formation of precipitation embryos the only controlling factor ?

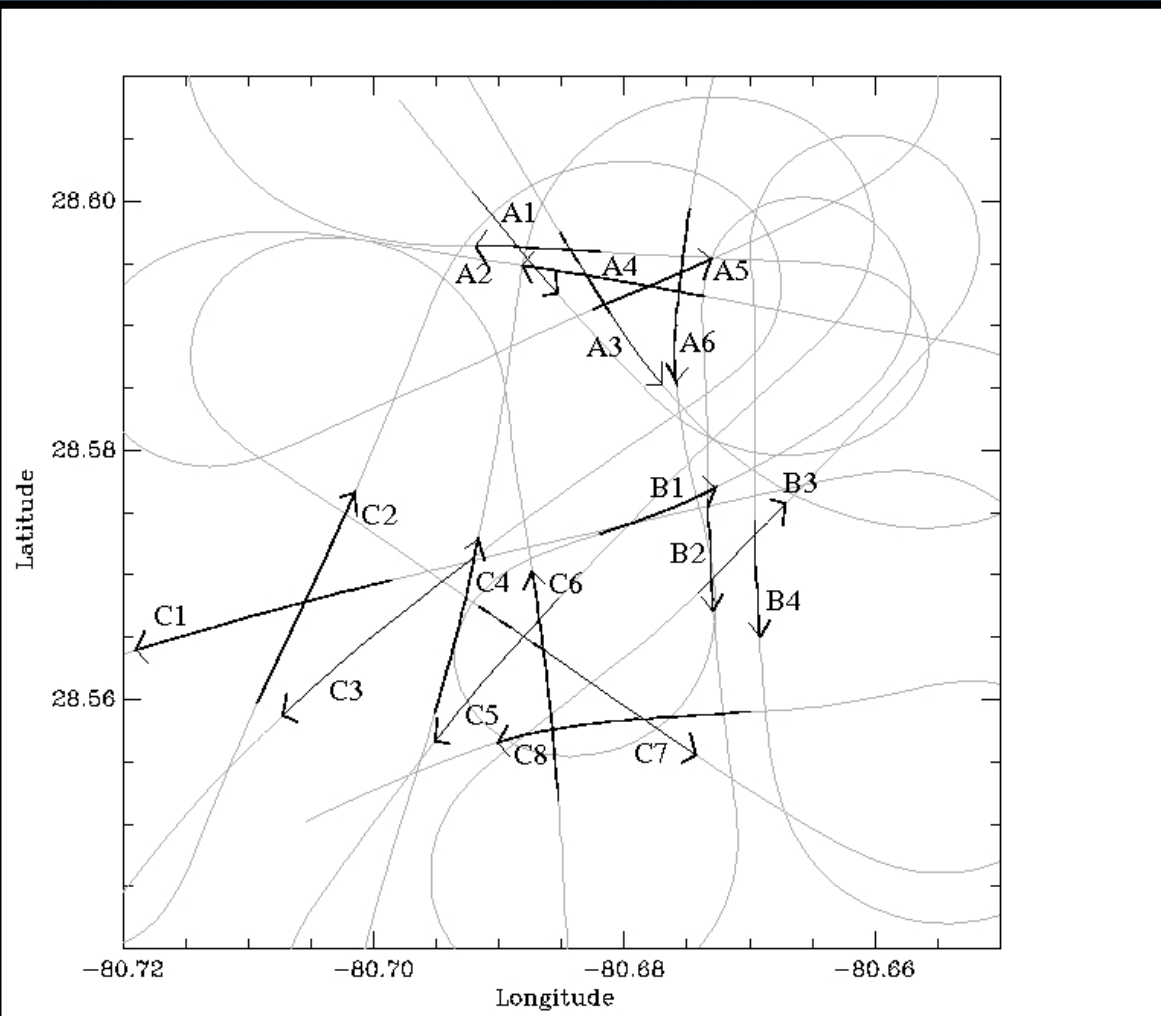
Small Cumulus Microphysics Study

July August 1995 Cape Kennedy

Measurements performed with the Météo-France Merlin-IV, on August 10, 1995

Temperature: Rosemount (corrected for wetting)
Humidity: Lyman-α

Microphysics:
King-Probe & PVM-100 (LWC)
Fast–FSSP [2-45 μm]
OAP-200X [34-310 μm]
OAP-230Y [200-6200 μm]



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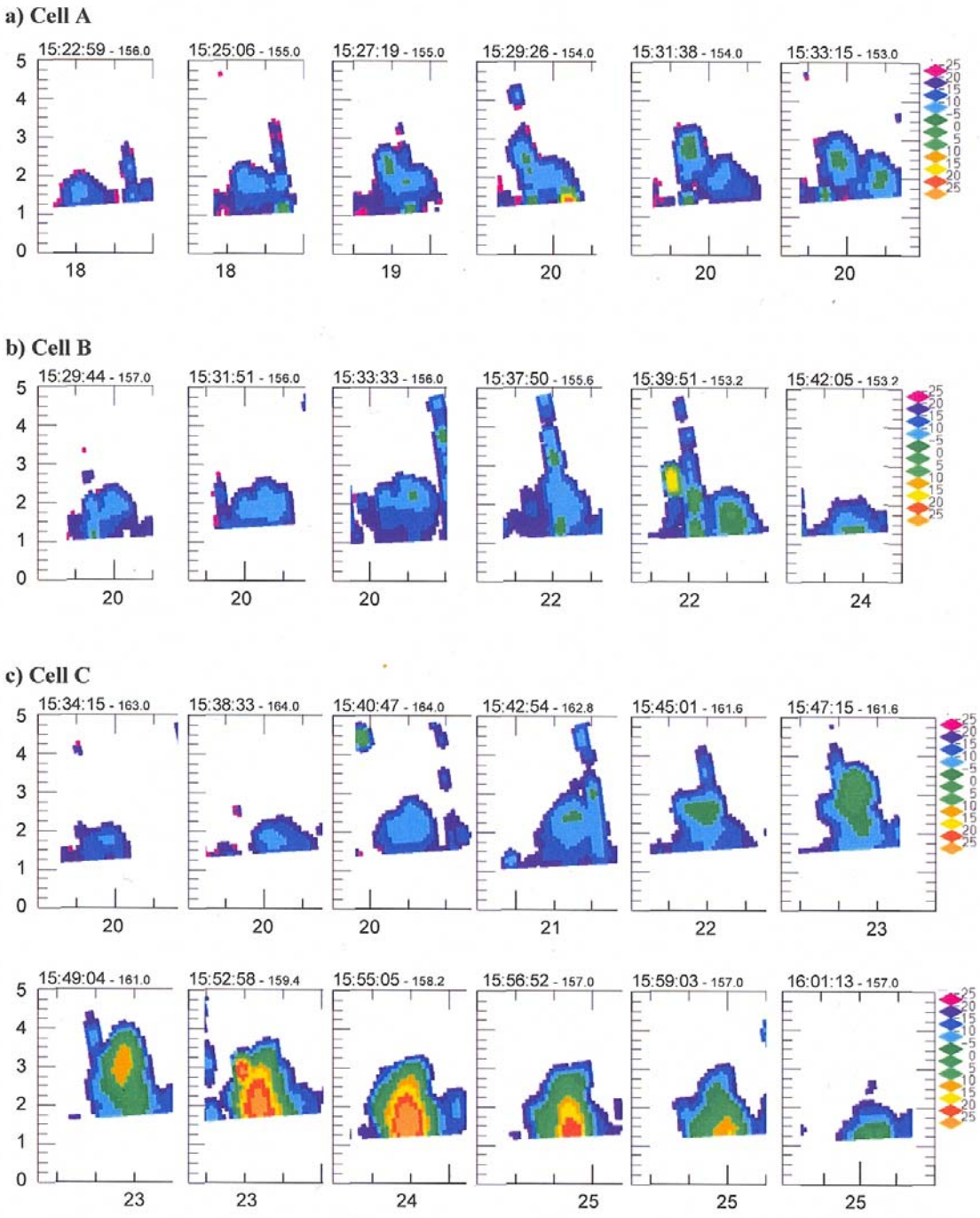
Sm udy



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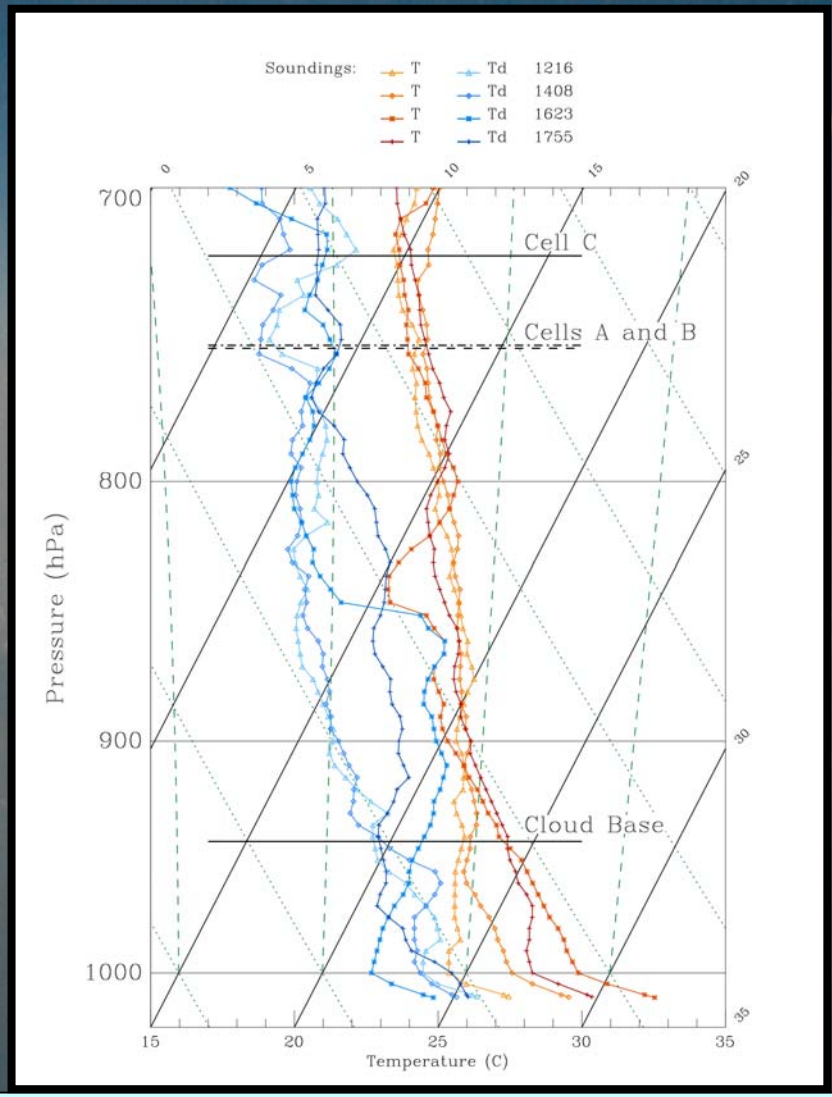
Meteorology on August 10, 1995

Three cumulus clouds were successively sampled from 15:26 to 15:55 UTC with the Merlin-IV at cloud top, while the NCAR-C130 and the UWYO-QA were sampling the same cloud at mid-level and at cloud base, respectively.

The two first clouds collapsed rapidly, while the third one reached higher levels and produced heavy precipitation.



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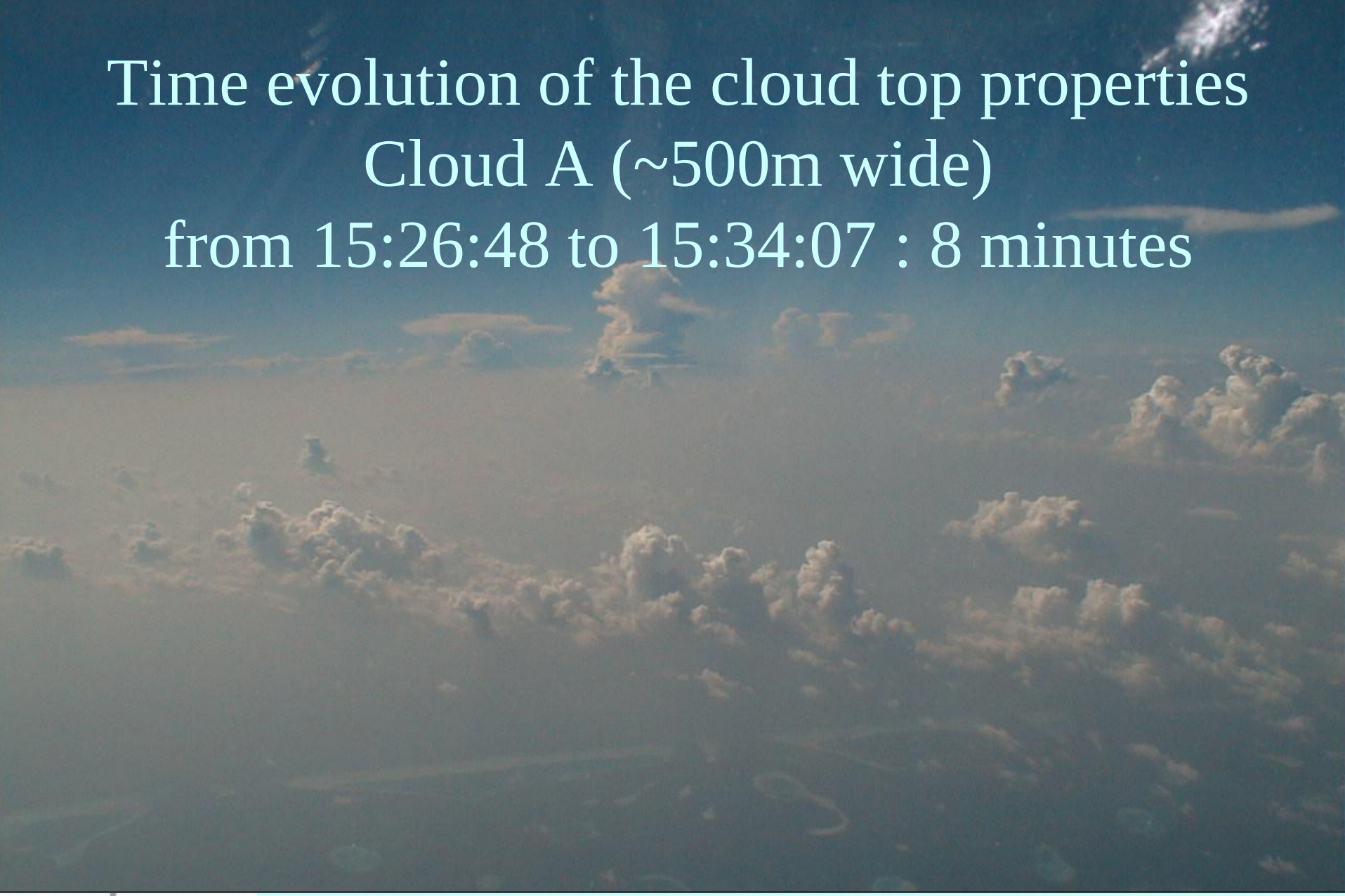
Time evolution of the cloud top properties
Cloud A (~500m wide)
from 15:26:48 to 15:34:07 : 8 minutes



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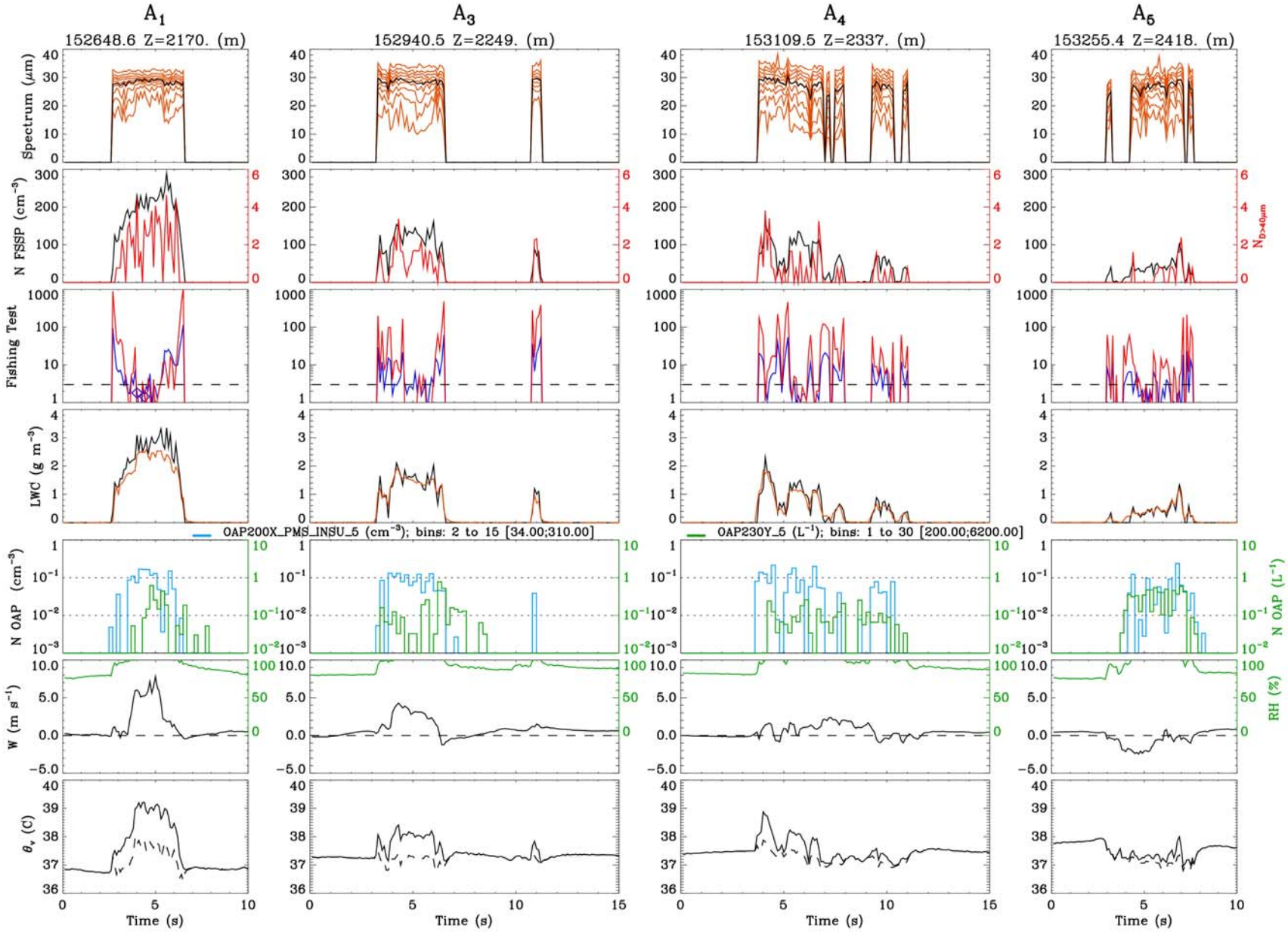

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Time evolution of the cloud top properties

Cloud A (~500m wide)
from 15:26:48 to 15:34:07 : 8 minutes

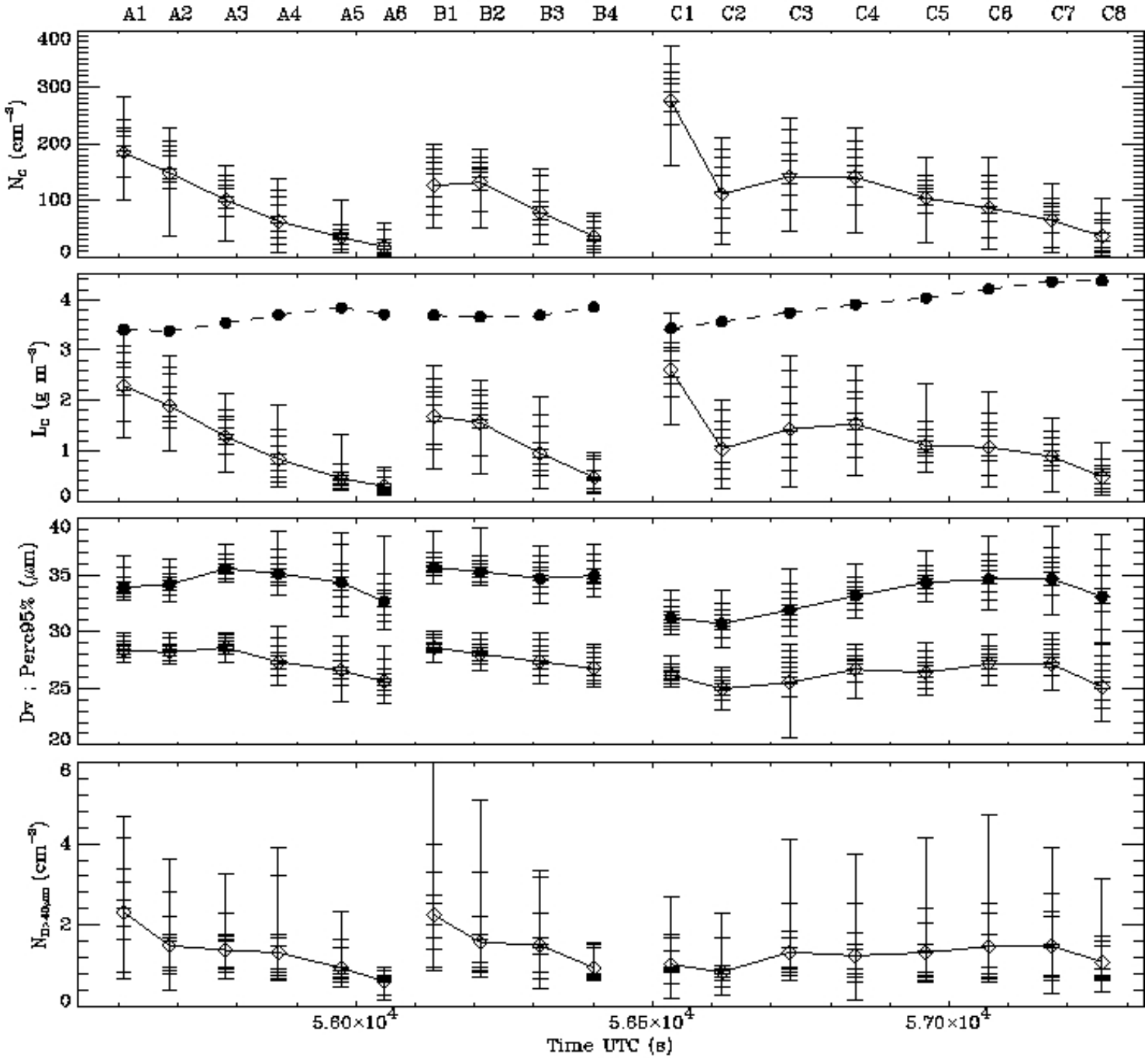
Cloud B (~700m wide)
from 15:35:31 to 15:40:01 : 5 minutes

Cloud C (~1.2 km wide)
from 15:42:11 to 15:54:17: 12 minutes

Statistics in each cloud section: mean and deciles

◇: cloud

●: adiabatic



Statistics in each cloud section: mean and deciles

1D-C

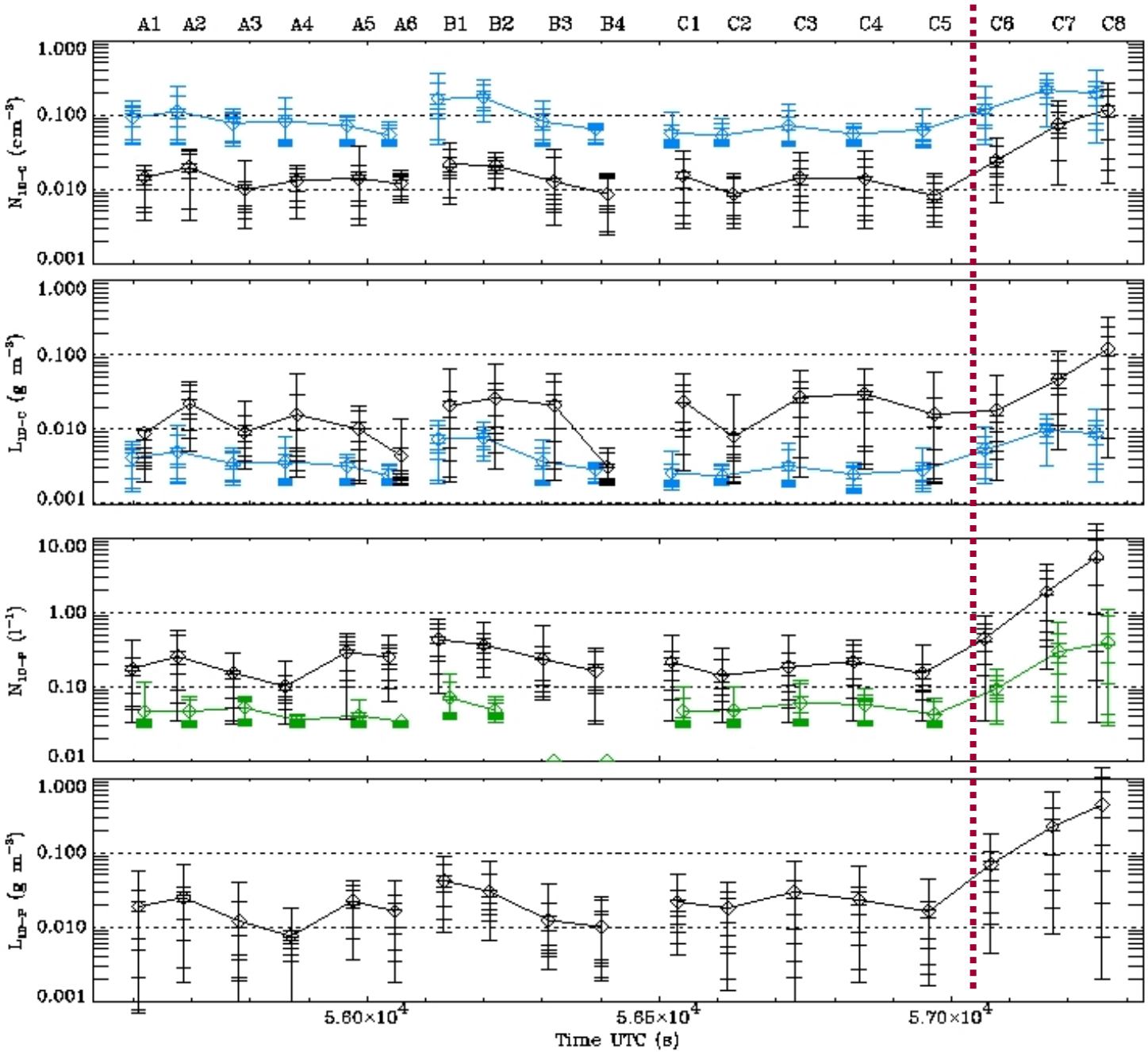
35-45 μm

45-310 μm

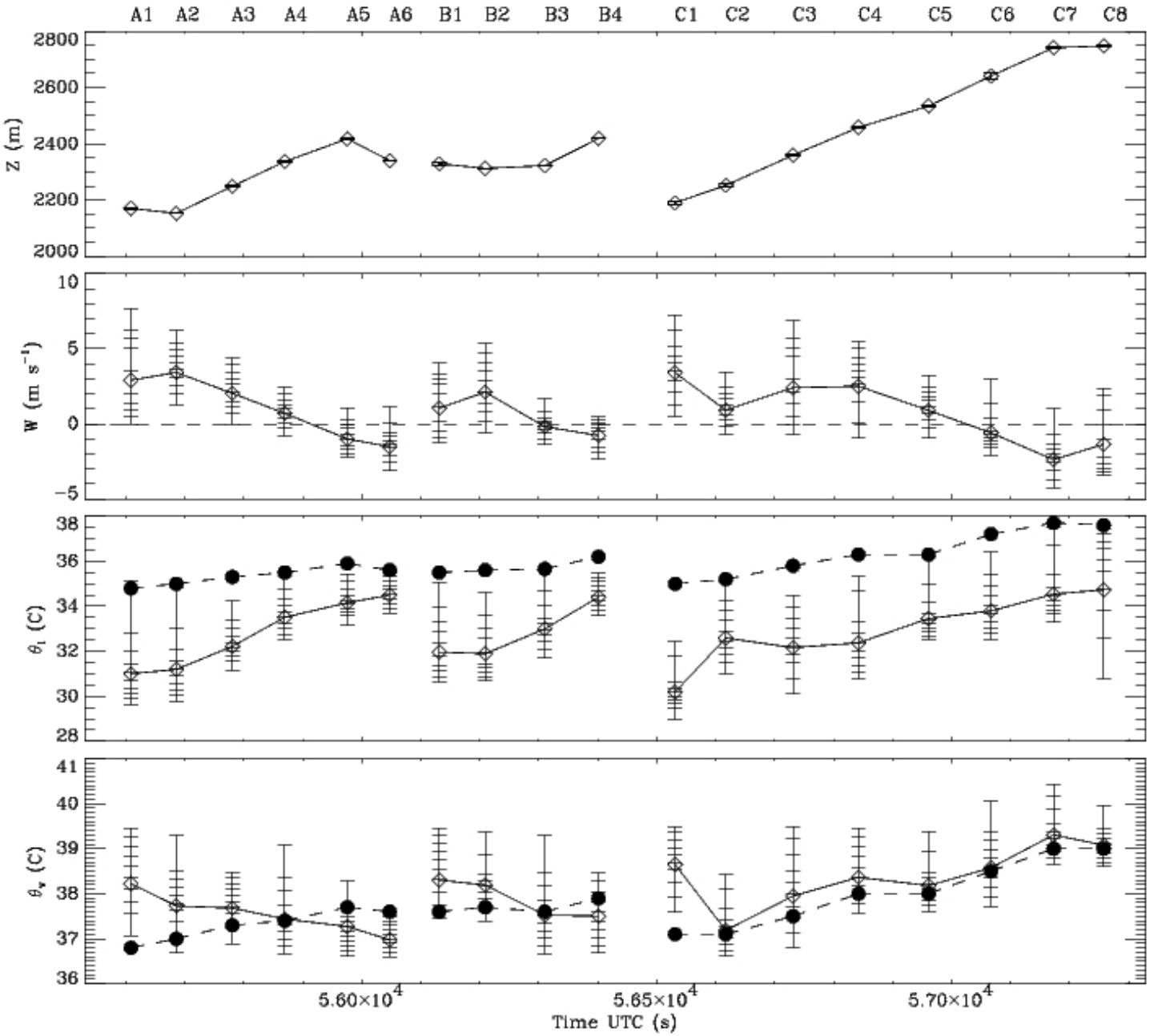
1D-P

D > 800 μm

200-6200 μm



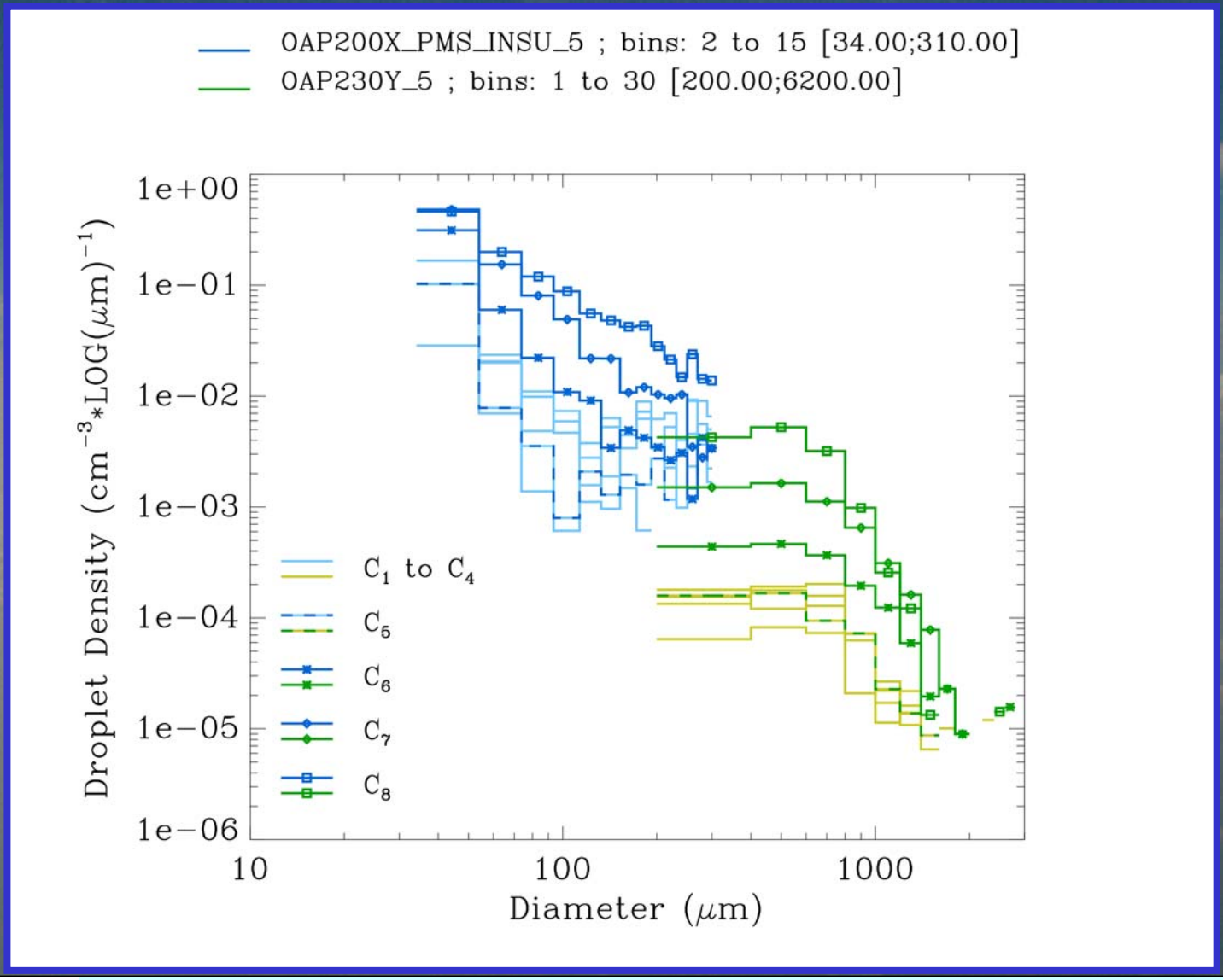
Statistics in each cloud section: mean and deciles



◇: cloud

●: environment

Precipitation formation in Cloud C



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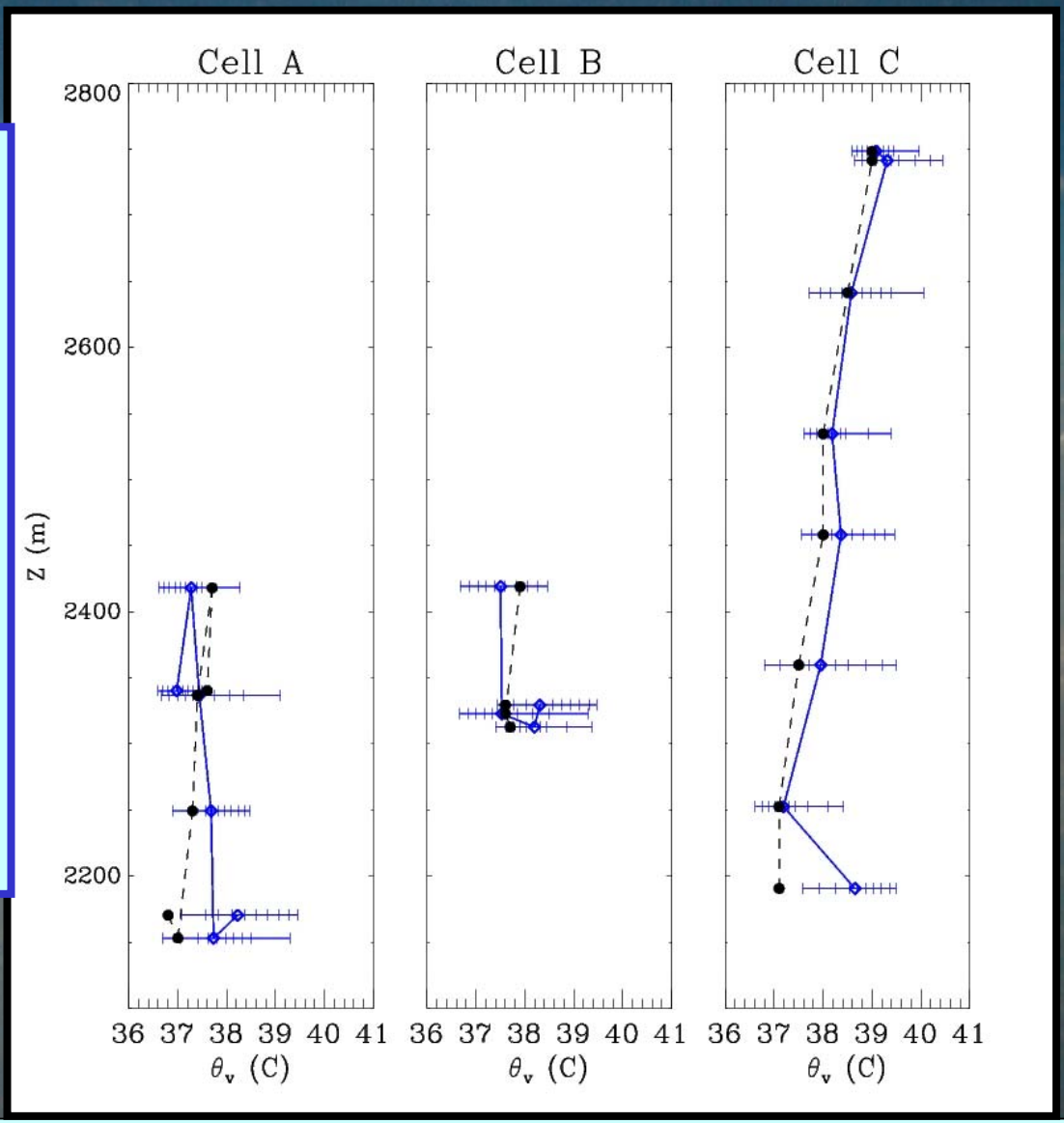
Precipitation formation in Cloud C

Vertical profiles of θv show noticeable differences:
Clouds A and B experience significant entrainment of environmental air and rapidly loose their buoyancy.
Cloud C in contrast remains buoyant up to 2750 m, which is sufficient for producing heavy precipitation.



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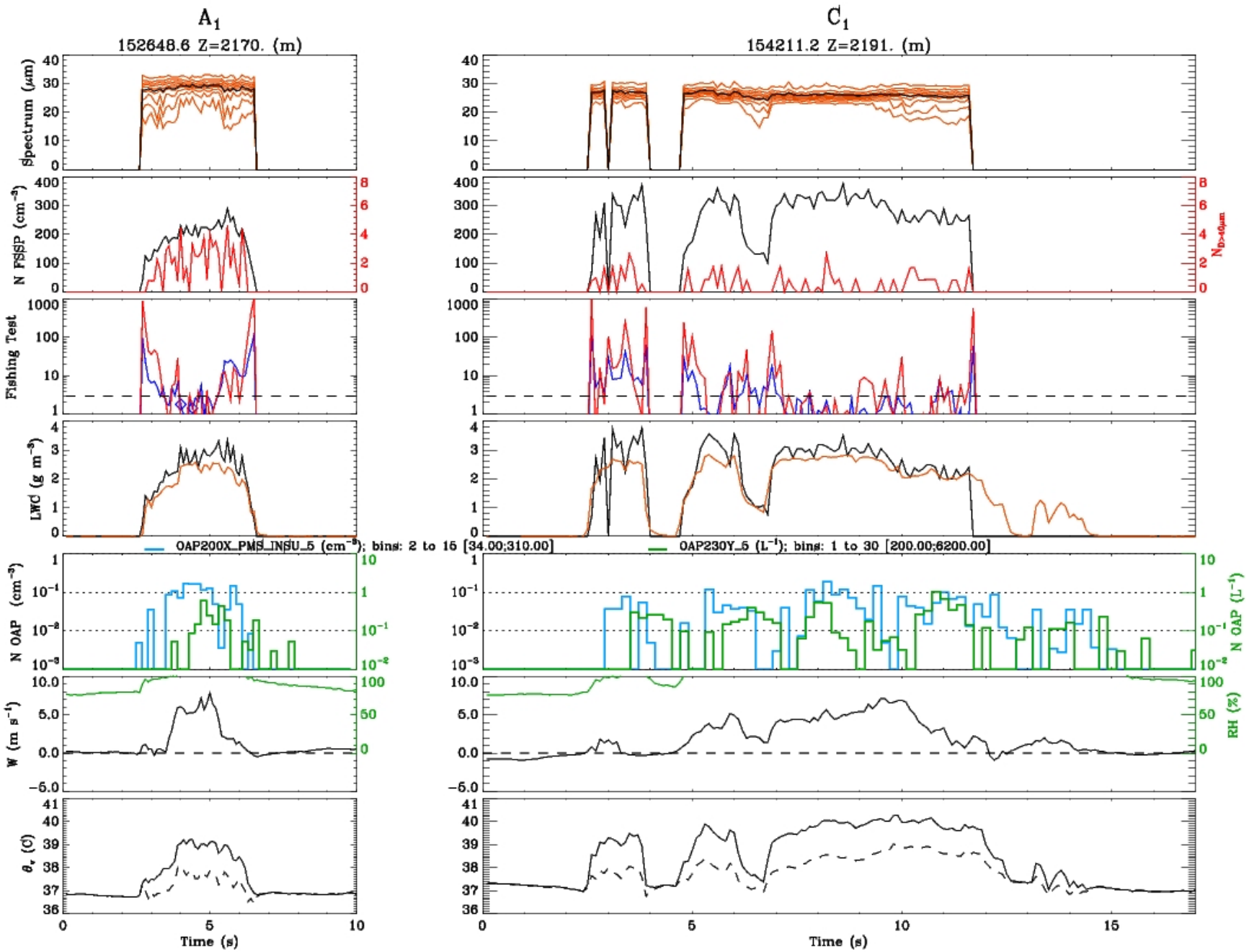
Conclusions

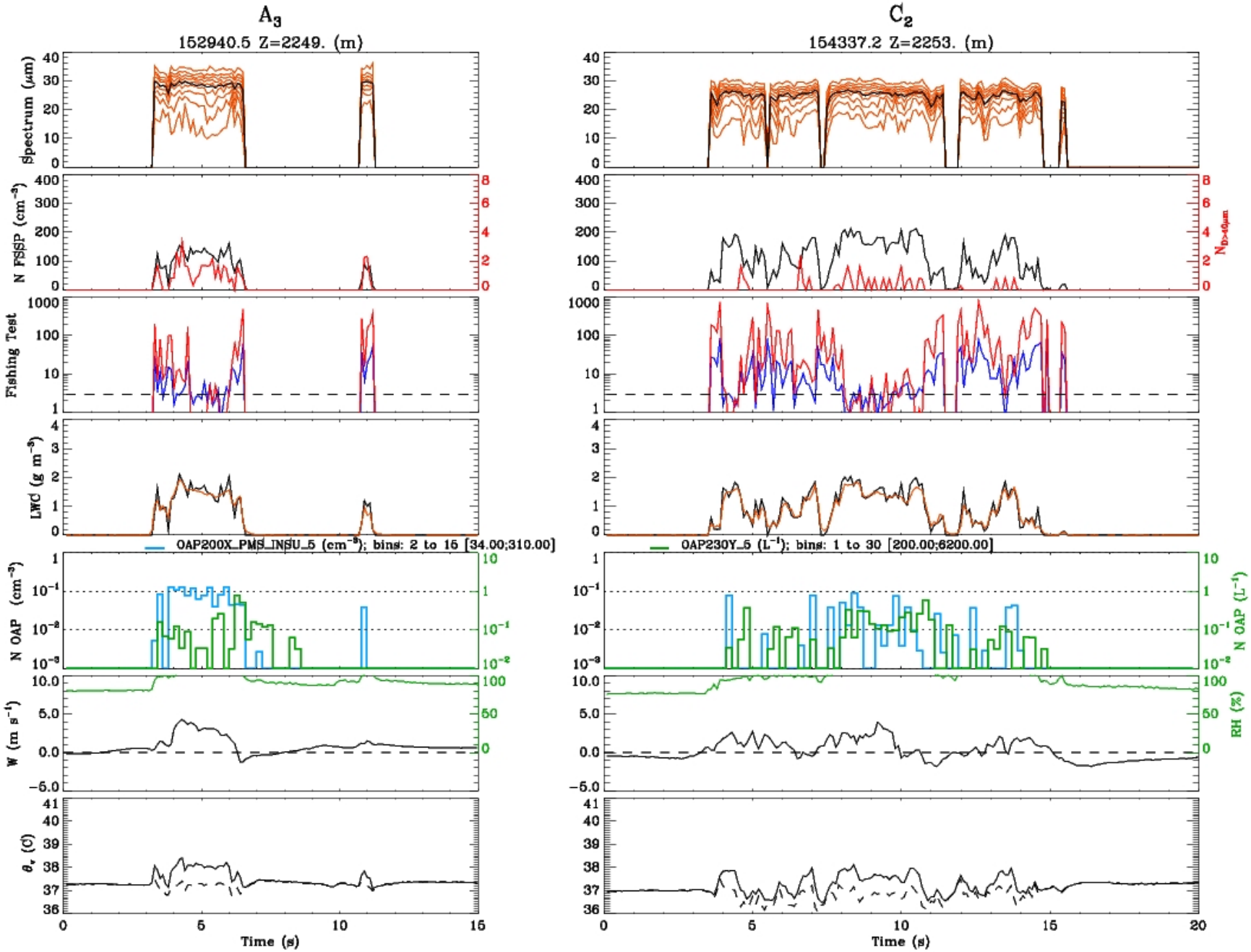
Three cumulus clouds growing in similar environments have been sampled, though progressive moistening of the environment is detectable.

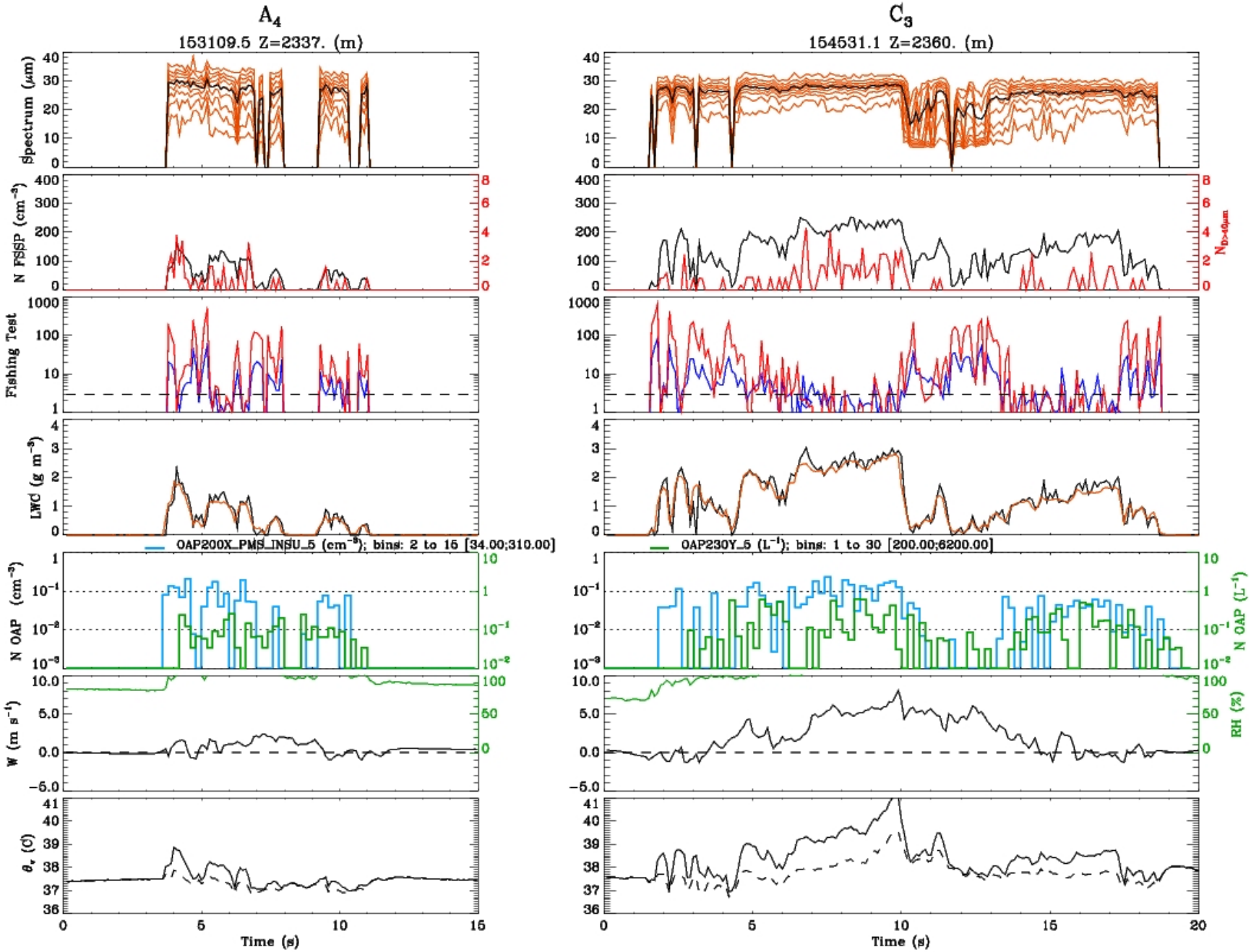
The three clouds are producing a noticeable concentration of precipitation embryos, but the first two clouds are collapsing before producing any precipitation, due to negative buoyancy following entrainment-mixing and droplet evaporation.

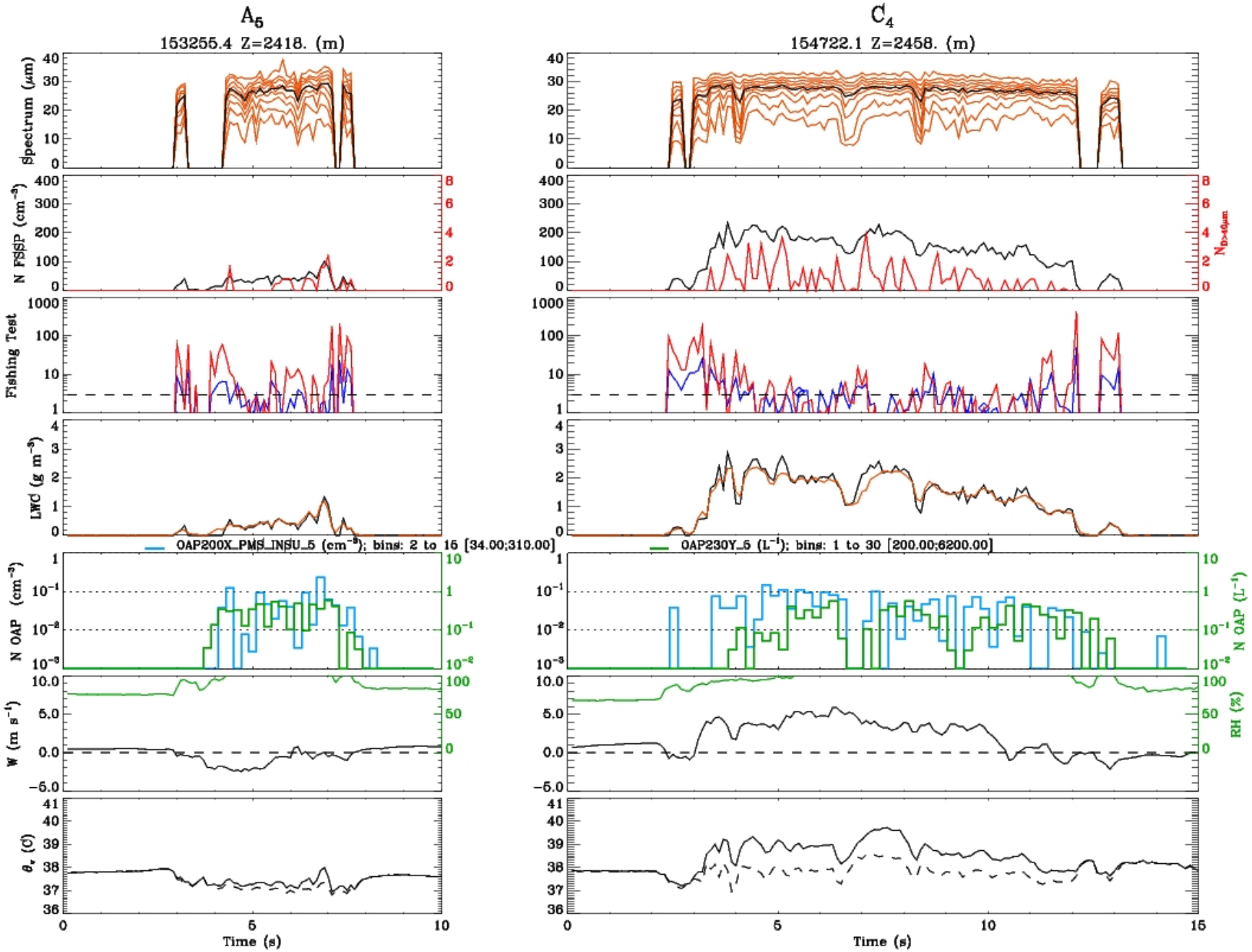
The third cloud is wider, with a stronger updraft intensity. It experiences less mixing, hence preserves its buoyancy. It thus reaches a higher altitude and produces heavy precipitation.

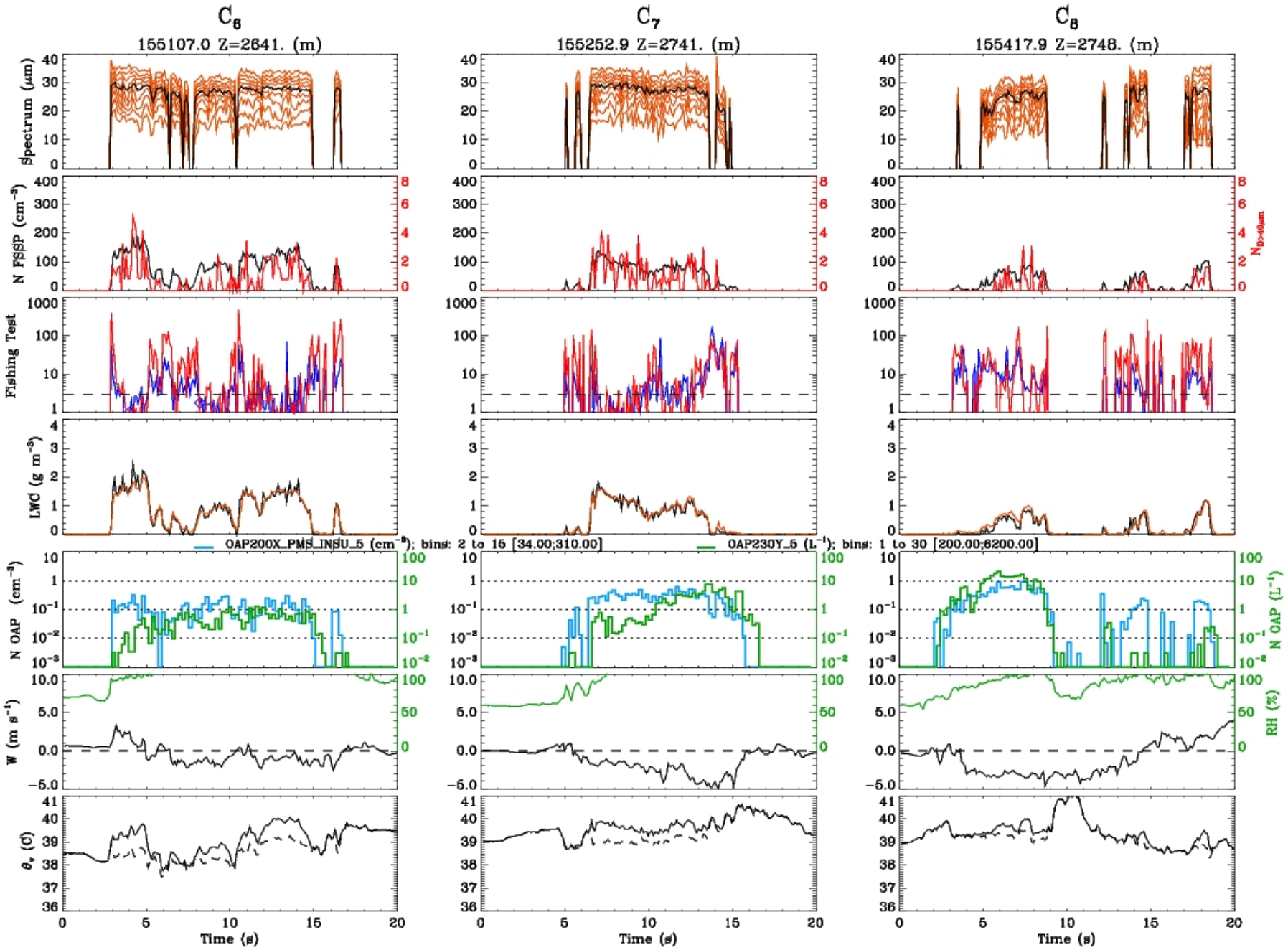
Precipitation embryos are necessary for the onset of precipitation, but the intensity of precipitation is mainly controlled by the vertical development of the convective cloud and the amount of cloud water available for collection.


A1
152648.6 Z=2170. (m)
C1
154211.2 Z=2191. (m)
Spectrum (μm)
N FSSP (cm⁻³)
Fishing Test
LWC (g m⁻³)
OAP200X_PMS_INSU_5 (cm⁻³); bins: 2 to 15 [34.00;310.00]
OAP230Y_5 (L⁻¹); bins: 1 to 30 [200.00;6200.00]
N OAP (cm⁻³)
N OAP (L⁻¹)
W (m s⁻¹)
RH (%)
θv (C)
Time (s)
Time (s)


A3
152940.5 Z=2249. (m)
C2
154337.2 Z=2253. (m)
Spectrum (μm)
N FSSP (cm⁻³)
Fishing Test
LWC (g m⁻³)
OAP200X_PMS_INSU_5 (cm⁻³); bins: 2 to 15 [34.00;310.00]
OAP230Y_5 (L⁻¹); bins: 1 to 30 [200.00;6200.00]
N OAP (cm⁻³)
N OAP (L⁻¹)
W (m s⁻¹)
RH (%)
θv (C)
Time (s)


A4
153109.5 Z=2337. (m)
C3
154531.1 Z=2360. (m)
Spectrum (µm)
N FSSP (cm⁻³)
Fishing Test
LWC (g m⁻³)
OAP200X_PMS_INSU_5 (cm⁻³); bins: 2 to 15 [34.00;310.00]
OAP230Y_5 (L⁻¹); bins: 1 to 30 [200.00;6200.00]
N OAP (cm⁻³)
N OAP (L⁻¹)
W (m s⁻¹)
RH (%)
θv (C)
Time (s)


A5
153255.4 Z=2418. (m)
C4
154722.1 Z=2458. (m)
Spectrum (μm)
N FSSP (cm⁻³)
Fishing Test
LWC (g m⁻³)
OAP200X_PMS_INSU_5 (cm⁻³); bins: 2 to 15 [34.00;310.00]
OAP230Y_5 (L⁻¹); bins: 1 to 30 [200.00;6200.00]
N OAP (cm⁻³)
N OAP (L⁻¹)
W (m s⁻¹)
RH (%)
θv (C)
Time (s)
Time (s)


C6
155107.0 Z=2641. (m)
C7
155252.9 Z=2741. (m)
C8
155417.9 Z=2748. (m)
Spectrum (μm)
N FSSP (cm⁻³)
Fishing Test
LWC (g m⁻³)
OAP200X_PMS_INSU_5 (cm⁻³); bins: 2 to 15 [34.00;310.00]
OAP230Y_5 (L⁻¹); bins: 1 to 30 [200.00;6200.00]
N OAP (cm⁻³)
N OAP (L⁻¹)
W (m s⁻¹)
RH (%)
θv (C)
Time (s)